

British Research Association
for the
Woollen and Worsted Industries

**The Relative Efficiency of
Different Types of Carding Engine
Working 46's Cross-bred Wool**

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ABSTRACT.

Parcels from the same blend were carded and spun at different mills and on different types of machines. The yarns and cloths were tested for strength and the behaviour of the cloth during the milling operation was observed. The variations in strength and count revealed were greater than some members of the trade expected, but, since the yarns were spun in a normal commercial manner, the results may be regarded as fairly representative of current practice.

It is shown that, provided the yarns are weavable, the variations in the cloth are smaller than those in the yarn, and the weaker yarns do not necessarily give the weaker cloths.

With regard to the output of tape condenser machines, the important conclusion is drawn that much greater outputs than are commonly obtained are possible. Generally, alterations would be necessary to get sufficient rubbing to admit of the larger outputs. Those members who are interested are recommended to experiment in this connection.

The results as a whole are very difficult to interpret on account of the large number of variables, not only in the machines, but also in the individuality and experience of the carding engineers.

For this reason it is satisfactory that it has been decided to instal at Torridon a carding engine and mule, with which it will be possible to change but one factor at a time, besides making alterations and trying new ideas which would be impracticable on machines placed temporarily at our disposal by our members.

INTRODUCTION.

Although there are certain well-marked differences in the carding engines used in districts where the staple trades are different, these differences in general are but little greater than those found in mills in the same neighbourhood working on the same class of trade. As an example of such a marked difference it may be stated that machines used for blanket work are generally clothed with coarser cards than those used for fine saxony cloths. On the other hand, if we consider either of these classes alone, we shall find in different mills considerable variations in speeds, sizes and numbers of swifts and doffers in the set, types of condenser, etc.

Further, it is well known that there are great variations in mill practice. The methods adopted by carding engineers working the same material to the same count may vary appreciably. There are, however, several broad principles on which general agreement is found. Thus it has been found by long experience that certain methods give the best results with given classes of material.

After due consideration by the Carding Committee it was felt that a series of experiments should be conducted in the hope of throwing some light on the reasons for these accepted principles. Among the

objects of the research was the important one of testing how far these accepted ideas are correct. For example, it is undoubtedly true that a machine fitted with double ring doffers will work a 46's cross-bred more satisfactorily than the same machine fitted with a tape condenser. Yet there are no records of systematic tests of this point. Such examples could easily be multiplied.

It was felt, therefore, that even if the experiments did no more than to confirm these current ideas, the record of the tests would be of no small value. Consequently the Committee accepted the kind offer of Messrs. C. & J. Hirst, Longwood, Huddersfield, to place at their disposal 5000 lbs. of a dark steel blend of about 46's cross-bred quality.* After blending, oiling and willowing, this was divided into 500 lb. lots. Various members of the Association were invited to card and spin these lots at a nominal rate, and to afford facilities for the recording of observations by the carding engineer and a member of the scientific staff. In this selection an endeavour was made to secure as large a variety of carding engines as possible, even to the extent of working the blend on machines of admittedly unsuitable type. By this combination of a practical engineer of long experience and a scientifically-trained observer, it was hoped to correlate the observations with the results of mechanical tests on the yarn and on the cloth woven from the yarn, and to see if the different methods of working the material were reflected in the milling property of the cloth, etc.

The general conclusions to be drawn from these experiments appear on page 17. Similar experiments on flannel and shoddy blends are nearing completion.

METHOD OF EXPERIMENT.

Our carding engineer did not work these batches himself. If, however, he thought any change desirable, he suggested the same to the engineer in charge of the mill. In each case the wool was put through as though it were a current blend.

The sizes, composition and arrangement of the machine, together with details of card clothing where these were available, were duly noted. All the speeds were taken, and the output of cardings was determined by observing the time required to fill the bobbins and weighing the wool thereon. No tests, other than the usual reeling tests of cardings and yarn, were made in the mills. It was considered preferable to take samples of the yarn and to test these under controlled conditions. In the humidity room at Torridon both temperature and relative humidity are controlled within comparatively narrow limits, so that tests made there are all made under the same conditions and are therefore strictly comparable. It is hardly necessary to

* The details of the blending are given in Appendix I.

emphasize the need for this, since the same woollen yarn or cloth is weaker and more extensible on a damp day than on a dry day.

The particulars of the mule were also recorded. These included the maker, number of spindles, length of draw and number of draws per minute. The twist in the yarn was observed by measuring with a counter the revolutions made by the spindles during a complete draw and dividing this by the number of inches in the length of the draw.

BRIEF DESCRIPTIONS OF CARDING ENGINES AND NOTES ON THE WORKING OF THE 500 LB. PARCELS.

In order to facilitate the comparison of the broad results of the tests at the different mills, the following table has been compiled. In it are shown the composition of the machine, the output % of yarn, soft waste, and fettlings, and the output of the machine in pounds per hour. The complete descriptions of the machines are given in Appendix II.

The percentage weights of yarn, soft waste and fettlings are calculated from the actual weights noted in the mills. In general they do not add up to 100%. The figures must be accepted with reserve, as output figures derived from a 500 lb. batch are unreliable, and are not representative of a large blend.

TABLE A.

Lot	Engine	No. of threads	Speed of 9" surface drums	Output % of oiled weight			Output of cardings in lbs. per hour
				Yarn	Soft Waste	Droppings and Fettlings	
A.	Breast and 3 Swifts, Scotch Feed, Tummer and 2 Swifts, Double Doffer Condenser	60	Top 18½ Bottom 17½	81.0	2.0	7.4	19.0 (10½ skeins)
B.	Breast and 2 Swifts, Scotch Feed, Tummer and 2 Swifts, Single Ring Doffer	50	29	78.0	5.0	11.6	25.8 (10 skeins)
C.	Same Machine as B.	50	29	80.0	5.0	11.6	25.8 (10 skeins)
D.	Breast and 3 Swifts, Scotch Feed, Lickerin, and 2 Swifts, Endless Tape Condenser	100	14	84.5	2.6	6.25	24.8 (10½ skeins)

TABLE A.—continued.

Lot	Engine	No. of threads	Speed of 9" surface drums	Output % of oiled weight			Output of cardings in lbs. per hour
				Yarn	Soft Waste	Droppings and Fettlings	
E.	Same Machine as D.	100	29½ 21	28.0 (29½ r.p.m.) 43.5 (21 r.p.m.)	9.4*	5.8	53.0 (29½ r.p.m.) 37.8 (21 r.p.m.) (10¼ skeins)
F.	Breast and 2 Swifts, Scotch Feed, Breast and 2 Swifts, Series Tape Condenser	96	15½	67.8 (mule) 6.7 (frame)	9.2	12.0	24.6 (12 skeins)
G.	Breast and 1 Swift, Balling Machine, Bank Feed, 1 Swift, Balling Machine, Bank Feed, 1 Swift, Scotch Feed, 1 Swift, Series Tape Condenser	90	32 22	39 (32 r.p.m.) 32.5 (22 r.p.m.)	9.2	18.3	51.5 (32 r.p.m.) 35.4 (22 r.p.m.) (11¼ skeins)
H.	Breast and 1 Swift, Balling Machine, Bank Feed, 1 Swift, Balling Machine, Bank Feed, 1 Swift, Scotch Feed, 1 Swift, Series Tape Condenser	60	41	68.7	8.5	4.5	52.5 (8½ skeins)
J.	Breast and 1 Swift, Balling Machine, Bank Feed, Tummer, 1 Swift, Scotch Feed, 2 Swifts, Single Ring Doffer	52	20	75.8	8.3	8.3	18.4 (10 1/5 skeins)

* One half of this consisted of cardings pulled up, because of insufficient rubbing.

Lot	Engine	No. of threads	Speed of 9" surface drums	Output % of oiled weight			Output of cardings in lbs. per hour
				Yarn	Soft Waste	Droppings and Fettlings	
K.	Breast and 2 Swifts, Scotch Feed, Breast and 2 Swifts, Endless Tape Condenser	120	13½	78.5	4.3	18.0	29.6 (10½ skeins)
L.	Breast and 3 Swifts, Scotch Feed, Breast and 2 Swifts, Series Tape Condenser	75	16	77.5	1.8	11.2	20 (10½ skeins)

Lot A.

The double doffer machine is usually considered the best type for a blend of this description. Beyond a speed variation of the whole machine of about 6%, the test proceeded without any notable incident.

Lots B and C.

The single stripper machine employed in this test embodies a number of special features. Intended for work of a very different character from this blend, the machine runs at a high speed. The test was begun with the swifts running at 85 r.p.m. and the surface drums running at 39 r.p.m., but after making one set of bobbins for the mule, the speed was reduced to 29 r.p.m., since the rubbing of the cardings was insufficient. At the lower speed the spin was better, but was not then really satisfactory. For Lot C the machine was speeded down to 65 r.p.m. for the swifts, because the action of the fancies was considered too violent when the swifts were making 85 r.p.m. To a certain extent this was an improvement, but since it involved a reduction in the speed of the rubbers it was not entirely an advantage.

Lots D and E.

Lot D was run on the tape condenser machine with the surface drums running at the usual speed of 14 r.p.m. Lot E was divided into two portions, which were worked at surface drum speeds of 29½ and 21 r.p.m. respectively. In order to get sufficient speed on the rubbers to admit of these high outputs, it was necessary to procure a larger rim pulley to drive the rubber eccentrics at a high speed. Both parts of Lot E required more twist in spinning than Lot D, in order to make the yarn sufficiently strong.

Lot F.

The principal feature of this test was that the cardings were made fully one skein lighter than at all other mills. A small portion of the cardings were spun on a spinning frame, the rest being spun in the mule.

Lot G.

This test was carried out on a different type of machine from the previous tests. The scribbler consisted of a breast and one swift, and the wool was taken from the doffer in the form of a sliver by a fly comb and made into balls. The intermediate, which was fed with 60 balls, was a single-part machine. The carder, also fed with 60 balls, consisted of two units connected by a Scotch feed.

The machine runs at a high speed throughout, and the first lot of cardings were made at a surface drum speed of 32 r.p.m. After examining the yarn in the mule, it was thought advisable to reduce the surface drum speed to 22 r.p.m., the resulting yarn being somewhat less rough. This, however, is not reflected in the coefficients of variability of the strength and count of the yarn calculated from the hank tests. (See later).

Lot H.

This lot was worked on a machine similar to that used for Lot G (except in the number of threads), but the cardings were made heavier ($8\frac{1}{2}$ skeins) and were drawn and spun in the mule instead of being spun direct. In the drawing operation, cardings of $8\frac{1}{2}$ skeins were spun, with the minimum possible left-hand twist to 12 skeins. These rovings were then spun in another mule with right-hand twist to the required count.

Lot J.

This lot was carded on a machine which, like that used for Lots B and C, can be regarded as very unsuitable for the purpose. With only 52 good threads on a carder 60" wide, the films on the doffer rings are very thin, and there is considerable tendency for the cardings to be irregular or "pointy." The principal difficulty is in the division of the threads.

Owing to a defect in the Scotch feed, the end threads were not of correct weight, and it was necessary to return to the hopper the cardings made before this fault was discovered. This may account partly for the low tests. Also the machine was not in good condition, the carder swifts particularly needing re-clothing. The machine had been running night and day for a number of years on 48/50's quality cheviots, making cardings heavier than $10\frac{1}{5}$ skeins, generally for drawing and spinning.

Lot K.

The tape condenser machine working this batch was ground up and put in good condition before beginning the test, which proceeded without any hitch whatever.

Lot L.

The machine used for this lot was a 75-thread, 3-height tape condenser. There was nothing specially notable about the test.

TESTING THE YARNS AND CLOTHS.

In this part of the work considerable difficulties were encountered. The first question for solution was the getting of a representative sample of the yarn from each lot. Ultimately the method decided upon was to take the cops at random along the mule during the doffing. In this way one could take cops corresponding to the different parts of the condenser bobbins. The number of cops taken (usually six) is very small, but in view of the weight of yarn on each it was generally impracticable to take more.

It was clear at the outset that the tests made could be comparative only. There appear to be no numerical criteria applicable to the results of the tests. Such standards can only be gradually found by testing yarns, which, in the opinion of practical men, are well carded and spun, to see what variations in strength and count are usual and unavoidable. For example, at present no one seems to be in a position to give a figure for the variations from the mean strength of a yarn, and to say definitely that below that figure the yarn is good, and above that figure the yarn is poor.

Care was taken to determine the count of the portions of yarn actually used for the strength tests. With variable material such as woollen yarns, single thread testing is probably the most satisfactory, though its practicability is open to question. For example, if 500 single thread tests on 18" lengths are made on a Baer or Goodbrand machine, only 250 yards, corresponding to 125 draws of the mule, are tested. These 500 tests would be nearly a day's work, and even if spread over a dozen bobbins or cops, could hardly be regarded as a fair test of the yarn from the mule of 300 or more spindles. To a certain extent this objection is met by the Moscrop machine, in which 6 bobbins are tested at a time and tests of strength at the rate of about 1500 per hour can be obtained. The length of the test piece taken in this machine was $11\frac{1}{4}$ inches.

A more satisfactory solution is provided by the hank test. A much larger quantity of material is tested than is possible with single thread tests, and it appears from an independent investigation that this method of testing is quite reliable.

An attempt was made to determine the twist in each sample of yarn. It is generally admitted that testing single yarns for twist admits of no great accuracy. The results showed very large variations from inch to inch along any particular yarn, and it was felt that such tests would certainly give far less reliable results than the observations taken on the mule spindles with a revolution counter. The values given for the turns per inch are therefore taken from the number of revolutions made by the spindles per draw, divided by the length of the draw of the mule.

In order to get a test of the cloths made from the different lots of yarn, a sample of each was woven as weft into the same warp, the pieces being clearly marked as the weft was put in. The cloth was a Colne Valley Tweed 16-17 oz. per yard. The strength tests were made on

the Goodbrand cloth testing machine, the test pieces being cut to give the strength of the weft. These tests are naturally somewhat difficult to interpret and correlate since the variations due to the irregularities in the warp affect the results to the same extent as those due to the weft.

Marks 36" apart were sewn into the lists in each sample between the scouring and the milling. The distances between these pairs of marks, together with the width of each sample, indicated the behaviour of the cloths during the milling operation.

RESULTS OF THE TESTS.

In the above section certain objections to different methods of testing woollen yarns for strength have been raised. After due consideration of the whole question, the authors feel that the hank test is worthy of greater confidence than the other tests. It is not suggested that its interpretation is free from difficulties, but as a comparative test on reasonable quantities of material it is fairly free from objection. The hank tests will therefore be given first, and the single thread and cloth tests later. The whole of the tests on the yarns and cloths were made in the humidity room at 72°F. and 68% relative humidity.

(a) The Hank Test.

The tests were made on hanks of 64 yards made on a 36" reel with a testing machine supplied by Messrs. Goodbrand & Co. The machine is power-driven, the rate of traverse of the lower hook being 12" per minute.

In general, in each lot of yarn 36 tests, viz., six hanks from each of six cops, were made. After breaking in the machine, each hank was weighed and its count was calculated. As a typical example of the results obtained, the tests on Lot A are shown in detail in Table B below.

TABLE B. HANK TESTS ON LOT A.

Strength (lbs.)	Count (Skeins)	Strength (lbs.)	Count (Skeins)
108	14½	113	15½
109	14¾	117	14¾
112	14½	127	13¾
107	14¾	123	14¾
98	15½	116	14½
93	16½	125	14½
116	14½	94	15¾
114	14¾	96	15¾
117	14½	93	16½
110	14¾	91	16½
106	16	93	16½
106	14½	86	17½
115	14¾	103	15
117	14	125	13¾
119	15	113	14¾
105	15¾	106	14¾
103	15¾	115	14½
117	15½	107	15
Total		3915	540¾
Average		109	15

Although the variations of strength and count in the above yarn were greater than the variations in some of the other lots, this lot was well carded and spun. It is therefore evident that a 25% variation in strength on each side of the average is not abnormal in woollen yarns.

In order to compare the several lots of yarn with each other, it is necessary to find the strength of each yarn at some standard count. The count chosen for this is 15 skeins, as this figure is not far from the general average. The method of calculating the strength at 15 skeins in those cases where the average count differs from this, is shown in Appendix III.

In the following table are shown the means of the results of the hank tests on each lot of yarn, and the strength reduced to the standard count of 15 skeins. The coefficients of variation of strength and count in the last two columns are measures of the irregularities of the yarns. These are explained at greater length in Appendix IV.

TABLE C.
SUMMARY OF HANK TESTS.

Lot				Observed Mean Strength lbs.	Observed Mean Count (Skeins)	Strength calcu- lated to 15 skeins lbs.	Twist turns per inch from Mule Spindle test. Turns per inch	Co- efficient of varia- tion of strength of yarn %	Co- efficient of varia- tion of count of yarn %
A.	...	...	...	109.0	15.0	108.8	9.3	9.53	5.23
{ B.	...	...	...	89.0	14.8	88.5	10.6	7.13	3.86
{ C.	...	...	...	91.0	14.9	90.7	10.6	8.40	4.60
{ D.	...	...	...	102.0	14.8	100.8	10.3	7.28	5.78
{ E.	29½ r.p.m.	...	...	88.0	14.3	83.5	11.8	7.29	4.62
	21 r.p.m.	...	...	91.0	14.9	90.0	11.8	6.42	4.13
F.	Mule	...	...	91.5	15.1	92.2	11.8	7.77	3.66
	Frame	...	...	82.7	15.4	84.7	—	6.26	3.95
G.	32 r.p.m.	...	...	99.7	14.8	98.6	11.6	10.76	7.35
	22 r.p.m.	...	...	107.8	13.8	99.3	11.6	14.41	10.97
H.	Drawn and Spun	...	...	86.0	15.8	90.9	13.2	7.76	3.29
J.	...	...	...	95.5	15.0	95.2	10.8	6.93	3.74
K.	...	...	...	93.9	16.5	103.1	10.3	6.72	4.78
L.	...	...	...	93.5	15.2	94.7	11.8	11.28	6.37

The strength should be read in conjunction with the coefficient of variation, because a yarn whose average strength is high may weave no better than one whose average strength is low, but which has a smaller coefficient of variation. For example, Lot A is stronger than

Lot F (Frame), but is more variable. Actually there may be as many, or even more, weak places in Lot A than in Lot F. Weak places are obviously of the greatest importance in weaving.

(b) Single Thread Tests on the Moscrop Machine.

The results of these tests are shown in the table below. In each case about 480 tests each $11\frac{1}{4}$ " long, 80 from each of six cops, were made, but it must be remembered that this number represents only about 1 oz. of yarn. An investigation not included in this paper showed that the relation between strength and weight for single yarn tests is similar to that for hank tests. Accordingly, these tests are reduced to the arbitrary count of 15 skeins by the method employed for the hank tests.

TABLE D.
SUMMARY OF SINGLE THREAD TESTS ON THE MOSCROP MACHINE.

Lot				Observed Mean Strength (ozs.)	Count (skeins)	Strength calculated to 15 skeins ozs.	Coefficient of variation of strength of yarn %
A.	...	...	...	17.0	15.0	17.0	15.1
{ B.	...	...	...	16.0	14.3	15.2	16.8
{ C.	...	...	...	16.2	14.3	15.4	16.3
{ D.	...	...	...	16.2	15.4	16.5	13.5
{ E.	29½ r.p.m.	...	...	15.0	14.1	14.1	17.7
	21 r.p.m.	...	...	15.2	15.0	15.2	15.5
F.	Mule	...	...	15.2	15.3	15.5	17.6
	Frame	...	...	13.7	15.5	14.0	21.5
G.	32 r.p.m.	...	...	16.6	15.2	16.8	16.8
	22 r.p.m.	...	...	18.4	13.4	16.4	18.5
H.	...	...	...	14.6	16.2	15.7	17.1
J.	...	...	...	16.0	15.2	16.2	17.0
K.	...	...	...	14.7	17.3	16.9	17.0
L.	...	...	...	15.9	14.9	15.8	19.9

It will be observed that the coefficient of variation of strength is about twice as great as that for the hank tests. This would be expected when the differences between the two types of test are remembered, for the hank test may be regarded as giving a value for the strength related in a comparatively simple manner to the mean strength of a number of single threads tested together. It is clear that in a series of single thread tests the individual results will show a greater variation than the averages of groups corresponding to the number of strands in a hank test.

(c) Single Thread Tests on the Baer Machine.

From each lot of yarn 120 tests (18" lengths) were made. The average strength is shown in the table below, together with the count. The strength at 15 skeins has been calculated as before.

TABLE E.

SUMMARY OF SINGLE THREAD TESTS ON THE BAER MACHINE.

Lot				Observed Mean Strength (ozs.)	Count (skeins)	Strength calculated to 15 skeins ozs.	Coefficient of variation of strength of yarn %
A.	...	...	...	15.8	15.8	16.7	14.0
{ B.	...	...	...	13.0	14.5	12.7	16.7
{ C.	...	...	...	13.0	15.5	13.5	13.7
{ D.	...	...	...	15.2	13.6	14.4	11.1
{ E.	29½ r.p.m.	...	...	10.9	15.0	10.9	15.5
	21 r.p.m.	...	...	13.1	15.0	13.1	11.4
F.	Mule	...	...	12.6	16.3	13.8	13.3
	Frame	...	...	13.1	15.0	13.1	21.8
G.	32 r.p.m.	...	...	14.2	14.8	14.0	18.2
	22 r.p.m.	...	...	14.4	14.8	14.2	24.4
H.	Drawn and Spun	...	...	14.1	15.0	14.1	14.9
J.	...	...	...	14.2	15.3	14.3	14.9
K.	...	...	...	14.9	15.0	14.9	16.7
L.	...	...	...	14.8	14.8	14.0	17.8

(d) Observations in the Scouring and Milling of the Cloth.

The piece containing the samples of yarn woven into the same warp was "licked" through 12° Tw. Soda Ash and scoured for 1½ hours, and was then washed off for half-an-hour. At this stage the strings, 36" apart warp-way, were put in each sample. The milling was done with 4 gallons of 8-10% of Colliers' soap. When this operation was complete the distances between the pairs of strings in the warp and the widths of the samples were noted. These are recorded in Table F below, the twist in the different samples of yarn being repeated from Table C.

The warp into which the samples of yarn were woven was of the same type and quality of wool as that from which the samples were spun.

TABLE F.
MILLING RESULTS.

Lot	Width (inches)	" Warp yard " (inches)	Twist in yarn
A.	56	34	9.3
{ B.	57	33½	10.6
{ C.	57	33½	10.6
{ D.	58	34½	10.3
{ E. 29½ r.p.m.	58	33½	11.8
21 r.p.m.	58	33¾	11.8
F. Mule	57½	33½	11.8
Frame	58½	34½	—
G. 32 r.p.m.	57½	34	11.6
22 r.p.m.	58	34½	11.6
H.	57	34	13.2
J.	57	34½	10.8
K.	57	33½	10.3
L.	56½	33½	11.8

(e) Strength Tests on the Finished Cloths.

The Goodbrand cloth testing machine with jaws 6½" apart was employed for this purpose. The test pieces were first cut roughly, and threads were then pulled from the edges until the pieces measured exactly 9" × 6½". They were cut to give the strength of the weft. The figures given are the averages, 18 tests being made from each.

TABLE G.
SUMMARY OF CLOTH TESTS.

Lot	Observed Mean Strength (lbs.)	Observed Mean Weight of Stamp Test Pieces (grams)	Strength calculated to 13.75 grams (lbs.)
A.	222.5	14.28	214.3
{ B.	224.6	14.53	212.6
{ C.	214.1	14.32	205.5
{ D.	217.4	14.12	211.7
{ E. 29½ r.p.m.	188.7	13.76	188.6
21 r.p.m.	183.9	13.70	184.6
F. Mule	192.9	13.77	192.7
Frame	211.2	14.06	206.6
G. 32 r.p.m.	222.9	13.82	221.9
22 r.p.m.	197.8	13.55	200.4
H.	188.3	13.49	191.4
J.	206.2	13.88	204.3
K.	213.3	13.62	215.4
L.	187.3	13.43	191.7

It is somewhat difficult to compare the tests on the different lots, since the average weights differ to such an extent. Taking Lot A as an example, the greatest, least and mean strengths were 235, 190 and 222.5 lbs. respectively, and the greatest, least and mean weights were 14.60, 13.97, and 14.28 grams respectively. To a certain extent this is not suprising, for we have the variations of the warp superposed on those of the weft, and it is readily conceivable that the several cloths behaved differently during the milling operation. For comparative purposes the strength at an arbitrarily-chosen weight of 13.75 grams has been calculated by the method used in reducing the yarn tests.

DISCUSSION OF THE RESULTS OF THE TESTS.

In order to compare the tests on the 14 lots of yarn and cloth, the results given in Tables C, D, E and G have been collected in the following manner. The strengths of all the yarns and cloths (reduced to the arbitrary standards) have been averaged, and this figure is represented by 100. Each individual strength has then been compared with this average. Thus, the figure for any particular yarn shows at once the percentage by which it is better or worse than the average. For example, according to the hank test Lot A is 15.3% above the average, whilst Lot H is 3.7% below. This has been done for the hank test, Moscrop test, Baer test and Cloth test. Then, assuming the hank test to be most reliable, the lots have been arranged in descending order of magnitude of this test.

Table H shows the results collected in this fashion.

TABLE H.

TESTS REDUCED TO 15 SKEINS AND EXPRESSED AS A PERCENTAGE OF THE MEANS OF THE TESTS ON ALL THE LOTS.

Lot	Hank Test %	Moscrop Test %	Baer Test %	Cloth Test %
Average	100	100	100	100
A.	115.3	107.9	120.6	106.6
K.	109.2	107.3	107.8	106.1
D.	106.9	104.7	104.1	104.3
G. 22 r.p.m.	105.4	104.1	102.7	98.8
G. 32 r.p.m.	104.6	106.6	101.9	109.3
J.	101.0	102.8	103.4	100.6
L.	100.5	100.8	101.9	94.5
F. Mule	97.8	98.5	99.5	95.0
H. Drawn and Spun	96.3	99.8	102.4	94.3
C.	96.2	97.9	97.7	101.3
E. 21 r.p.m.	95.4	96.6	94.5	91.0
B.	93.8	96.6	91.8	104.8
F. Frame	89.8	89.0	94.5	101.8
E. 29½ r.p.m.	88.6	89.6	79.2	92.8

There is in this table very clear correspondence between the hank and single thread tests. It is true that these three tests do not place the yarns in exactly the same order when they are arranged according to the magnitude of the strength, but the differences are of a very minor character. The cloth test does not come so well into line.

But in making these comparisons, the twist in the yarns has been entirely neglected. Attempts were made to find the relation between strength of the yarns and the twist,* but it was not found possible to correct the figures in Tables C, D and E. It will be observed that the yarn from the double doffer machine (Lot A) has required the least twist, yet it is the strongest, and has also given one of the strongest of the cloths.

Considering the strengths according to the hank test alone, there are several interesting points. Lots D and E show the effect of increasing the output on a tape condenser machine. Corresponding to surface drum speeds of 14, 21, and $29\frac{1}{2}$ r.p.m., we have strengths of yarn of 106.9, 95.4 and 88.6 lbs. This is a valuable result, since the only changes made were in the speeds of the surface drums and rubbers. Incidentally, the slivers carded at 21 and $29\frac{1}{2}$ r.p.m. required more twist than those carded at 14 r.p.m. The result of the similar experiment on Lot G, however, shows no appreciable effect upon the strength of the yarn due to an increase in output in the ratio 32:22. It is clear, therefore, that some speeding-up is not necessarily harmful.

The single stripper machines, on which Lots B, C, and J were carded, also show the effect of increasing output. Lots B and C were worked on the same machine at 25.8 lbs. per hour. Lot J was worked on a similar machine at 18.4 lbs. per hour. The latter yarn is certainly the stronger. The difference between Lots B and C lies in the fact that the swifts were speeded down from 82 r.p.m. to 65 r.p.m. for Lot C. The output was retained at its previous value. It is seen that this has made the yarn slightly stronger, though the loss of rubbing power (reduced in ratio 65 to 82) must not be forgotten.

Bearing in mind the twist in the yarn, it appears that the double doffer machine (Lot A) has undoubtedly given the strongest yarn; Lots K and D, worked on tape condenser machines, compare well with Lot A. The other lots, carded on tape condenser machines, have required more twist and are not so strong. These tests confirm the opinion that the double doffer machine is the best for this class of wool.

For certain work the tape condenser is capable of greater output. Thus, Lot E was worked at 37.8 and 53 lbs. per hour, and gave yarns

* In the first attempt the twist in a sample of yarn was increased and decreased in a worsted roving frame, but it was found impossible to do this without drafting. The second attempt was to spin exactly similar material to the same count with three different twists. The wool was carded on a double doffer machine, and it was found impossible to put as much twist into the yarns as was put into some of the tape condenser yarns. The relation between strength and twist was found, but it was clear that the same relation would not hold for yarns carded on tape condensers or single strippers. The study of the correction for twist was therefore postponed until there is a machine running at Torridon.

which were weavable. It is true that even with extra twist they are not so strong as the yarn carded at 24.8 lbs. per hour, but for certain purposes they certainly would be quite good enough. The condenser, however, oscillates considerably at $29\frac{1}{2}$ r.p.m. of the surface drums. On the other hand, Lot G (32 r.p.m.) gave a yarn that was well up to strength, and a quite satisfactory cloth. It is evident, therefore, that outputs of 50 lbs. per hour are possible with the tape condenser, and that the question is worthy of further investigation. It is possible that when the difficulty of rubbing is surmounted the extra twist might not be necessary.

It is difficult to see any clear indications leading to definite conclusions in the measurements of length and width of the cloth after milling. It would appear, as is to be expected, that Lot A with the smallest twist has milled most readily. There is, however, no general correspondence between twist in the yarn and width after milling.

The strength tests on the finished cloths afford less assistance in the comparison of the products from the different machines than those on the yarns. The scouring and milling and finishing have evidently introduced new factors, the total effects of which tend to mask the initial differences in the yarns composing the wefts of the different cloths. Nevertheless it is generally true that the strongest yarns have woven into cloths of above the average strength.

From Lots G and H, carded and spun by the same firm, direct spinning may be compared with drawing and spinning. In the direct spinning, cardings of $11\frac{1}{4}$ skeins were spun with 837 turns per 72" net draw at 28 secs. per draw. In the drawn and spun lot, $8\frac{1}{4}$ skein cardings, were drawn to 12 skeins with 297 turns of left-hand twist per 72" net draw, each draw occupying 15 secs. These rovings were then spun to the nominal count with 1144 turns of right-hand twist (i.e., 924 turns net after allowing for spindle draft) per 70" net draw, the time per draw being 34 secs.

Thus, roughly, the machine time is reduced in the proportion $8\frac{1}{4}$ to $11\frac{1}{4}$, whilst the mule time is increased in the proportion $15 + 34 = 49$ to 28. It must be remembered, however, that in drawing and spinning the material is subjected to much more spindle draft, and irregularities should therefore be less prominent than in the yarn spun by the direct method. Also, cardings of $8\frac{1}{4}$ skeins should be relatively more regular than those of $11\frac{1}{4}$ skeins. The coefficients of variation of strength and count of the yarns confirm these deductions. It should be noted, however, that some of the lots by other firms have given yarns at least as regular without the double process.

CONCLUSIONS.

It was anticipated that there would be difficulties in the interpretation of the results of these experiments. A concrete example will

make clear the extreme need for caution in drawing conclusions. In comparing the results of the test on the double doffer machine (Lot A) with, say, that on a tape condenser machine (Lot D), the principal change to be considered is in the condenser. But, in addition, we have an entirely different carding engine, different engineer, differences in card clothing, setting, speeds, and a host of other factors. These experiments afford no means of proving that these minor differences do not together outweigh the principal difference, and we must therefore draw conclusions in a very guarded manner.

It seems, however, that the experiments point to the following conclusions :—

- (1) The double doffer machine used for Lot A is the most suitable for this class of work. Tape condenser machines running at a moderate speed for the surface drums, will make cardings which spin into very satisfactory yarns, but which require more twist than yarn from the double doffer machine. Of the single stripper machines used in these experiments one proved definitely unsuitable, whilst the other gave a yarn above the average. There is considerable lugging of the slivers in the single stripper machines in consequence of imperfect division, and the rubbing is also usually inadequate.
- (2) Yarns spun from cardings of 10 to 10½ skeins were the strongest. If the slivers were condensed to finer counts the yarn was weaker.
- (3) Yarn drawn and spun from heavier cardings is definitely weaker than yarn spun direct. Greater output from the carding engine is possible when the spinning is thus carried on.
- (4) Where there is a margin of strength and twist, appreciably greater outputs may be obtained from tape condenser machines. Experiments with a view to greater output should certainly be carried out, where the necessary spindles to follow the carding engine are available.
- (5) Fancies which are gentle in their action appear to be necessary for this class of material.
- (6) In several of the mills in which this blend was worked, the opinion was expressed that the wool was insufficiently oiled. The suggestion was also made that it would have worked better if watered a little. These points require experimental test.
- (7) Although the range of speed of swifts, etc., covered in these experiments is considerable, it is difficult to draw definite conclusions, particularly when the effect of other variables is considered.
- (8) The results of these experiments disclose no simple general relation between output of the carding engine and the strength of the yarn.
- (9) The close parallel between the single thread and the hank tests justifies the latter, which more readily give results on representative samples of yarn. Single thread tests, as normally carried out, are of little use.

(10) Cloth tests do not afford so much help in comparing the products of the experiments as the yarn tests. This objection would probably have less weight if warp and weft were the same.

APPENDIX I.

Blend 46's Cross-bred { 3770 lbs. Logwood Black.
1180 lbs. White.

BLENDING AND WILLOWING.

1st Operation.—Double Swift Fearnought 4' 6" wide.

Swifts 48" diam. 160 r.p.m.

Workers 6" „ 24 „

(4 on each

Swift).

Strippers (do.) 5" diam., 20 r.p.m.

Teeth 1" on 1st Swift, $\frac{1}{2}$ " on last Swift.

Fan 22" diam. 668 r.p.m.

Hopper 48" wide.

Comb 150 r.p.m.

Feed Sheet 20 r.p.m.

2nd Operation.—Piling and Oiling.

Wool put down in 16 layers.

1 gallon of Price's heavy oil per 100 lbs. of wool.

Oil applied with can.

3rd Operation.—Teasing.

APPENDIX II.

PARTICULARS OF CARDING ENGINES, MULES, etc.

LOT A.

Cliffe's Hopper Feed

Scribbler 60" wide—Crossed Belt Drive—Wooden Machine.

3	Feed Rollers	1 $\frac{3}{4}$ " diam.	16's n.p.		
	Lickerin	10 $\frac{1}{4}$ " „	16's d.p.		
	Lickerin Angle	4 $\frac{1}{4}$ " „	40/4		
	Breast	32" „	40/4	23g	46 r.p.m.
2	Workers	7 $\frac{3}{4}$ " „	(Double Convex 30/6)		8 „
			(Ordinary Wire 60/6)		
2	Strippers	4" „	60/6	24g	90 „
	Fancy	12" „	40/4	24g	208 „
	Doffer	25" „	40/4	Convex	11 „
	1st Angle	6" „	60/6	24g	172 „
	Swift	50" „	90/9	30g	78 „
4	Workers	7 $\frac{1}{2}$ " „	90/9	31g	5 „
3	Strippers	4" „	90/9	31g	276 „
	Fancy	11 $\frac{1}{4}$ " „	60/6	26g	384 „
	Doffer	23" „	90/9	30g	5 „
	2nd Angle	6" „	80/8	31g	262 „
	Swift	50" „	100/9	32g	78 „
4	Workers	7 $\frac{1}{2}$ " „	100/9	31g	5 $\frac{1}{2}$ „
3	Strippers	4" „	80/8	28g	202 „
	Fancy	12" „	65/7	28g	326 „
	Doffer	24" „	100/9	33g	6 „

	3rd Angle	6½" diam.	80/8	28g	264 r.p.m.
	" Swift	50" "	130/10	34g	78 "
4	" Workers	7¼" "	130/10	34g	4½ "
3	" Strippers	4½" "	80/8	28g	224 "
	3rd Fancy	11¼" "	65/7	31g	412 "
	" Doffer	24" "	130/10	35g	5 "
	Dick Roller		80/8	30g	8 "
	Fly Comb and Scotch Feed.				

Carder 60" wide—Crossed Belt Drive.

	2 Feed Rollers	2¼" diam.	16's n.p.		
	Clearing Roller	2¼" "	65/6	24g Fillet	
	Tummer	8¼" "	Garnett		45 r.p.m.
	1st Angle	5½" "	60/6	26g	186 "
	" Swift	50" "	130/11	34g	62 "
4	" Workers	7¼" "	130/11	35g	5½ "
3	" Strippers	4½" "	100/9	30g	164 "
	1st Fancy	11¼" "	70/7	32g (single bend)	280 "
	" Fly Stripper	2½" "	80/8	28g	210 "
	" Doffer	29¼" "	130/11	36g	8 "
	2nd Angle	5½" "	100/9	32g	172 "
	" Swift	50" "	135/11	36g	60 "
3	" Workers	8¼" "	130/11	36g	5 "
3	" Strippers	4½" "	100/9	32g	206 "
	" Fancy	11¼" "	70/7	32g (double bend)	340 "
	" Fly Stripper	2½" "	80/8	28g	308 "
	Double Ring Doffers	30" "	135/12	36g	4½ "

Chadwick Condenser.

Upper Surface Drums 9" diam. 18½ r.p.m. Rings ⅞" wide, waste 1½" wide.

Lower " " " 17½ " Rings 1" wide, waste 1½" wide.

Double Tandem Rubbers.

Rubber Eccentric 310 r.p.m.

60 good threads and two waste threads.

Settings. 26g for Scribbler.

28g for Carder.

Condition of Machine.—Some parts were in excellent condition and some otherwise. The machine was purchased with card clothing complete, and only a few of the rollers had been re-clothed. This may explain the somewhat peculiar counts and crowns of the clothing on scribbler. No record of these was available, and the figures given above were supplied by the carding engineer.

Speed Variation.—During this test the speed of the scribbler varied from 80 r.p.m. to 75 r.p.m. for a time, and that of the carder 65 r.p.m. to 60 r.p.m. In consequence the cardings ranged from 11¼ skeins to 9½ skeins.

Spinning.—Asa Lees Mule—360 Spindles.

6' 11" gross draw. 3" jack up, giving 6' 8" net draw.

745 turns per draw, i.e., 9.3 turns per inch.

Roller delivery 4' 9".

This mule was fitted with a patent carriage twist motion for keeping the exact twist. The twist motion was geared to the rim pulley shaft inside carriage, thus preventing backing off until the requisite number of turns had been put in.

Output.	Weight of Wool	...	...	...	500 lbs.
	" Yarn	...	...	...	404 "
	" Spinning and Condenser Waste	10			"
	" Fettleings and Droppings	...	...	37	"

The machine was not fettled before the test began, thus favouring the output somewhat.

Output calculated from speed of surface drums and weight of cardings, 19 lbs. per hour.

LOTS B & C.

Automatic Hopper Feed—Door fitted with balance weights.

Scribbler. 60" wide—Crossed belt drive.

Lickerin and Feed Rollers—Garnett.

	Breast	50" diam.	60/6	26g	46 revs.
4	" Workers	9" "	60/6	26g	36 "
3	" Strippers	4" "	40/4	23g	
	" Fancy	12" "	40/4	24g Sheet	
	" Doffer	36" "	60/6	26g	14 "
	1st Angle	6" "	60/6	26g	
	" Swift	50" "	110/10	30g	85 "
4	" Workers	9" "	110/10	30g	32 "
3	" Strippers	4" "	80/8	28g	
	" Fancy	12" "	60/6	26g Fillet	
	" Doffer	36" "	110/10	30g	16 "
	2nd Angle	6" "	90/8	28g	
	" Swift	50" "	120/10	34g	85 "
4	" Workers	9" "	120/10	34g	34 "
3	" Strippers	4" "	90/9	33g	
	" Fancy	12" "	70/7	27g Fillet	
	" Doffer	36" "	120/10	34g	10 "

Fly Comb and Scotch Feed.

Carder. 60" wide. Crossed Belt Drive.

	3 Feed Rollers		16's n.p.		
	Tummer		80/8	28g	
	1st Swift	50" diam.	135/11	35g	80 revs.
	" Workers	9" "	135/11	35g	28 "
	" Strippers	4" "	100/10	34g	
	" Fancy	12" "		28g sheets (setting loose)	
	" Doffer	36" "	135/11	35g	14 revs.
	2nd Swift	48" "	135/11	35g	82 "
	" Workers	9" "	135/11	35g	31 "
	" Strippers	4" "	100/10	34g	
	" Fancy	12" "		28g Fillet Twill	
	Ring Doffer	31½" "	135/12	35g	6 "

50 good threads, 2 waste threads.

Rings $\frac{7}{8}$ " wide. Spaces $\frac{1}{4}$ " wide.

Single rubber with iron roller about 2" diam. covered with rough emery on top of sheet.

Surface drums 9" diam.

Settings. Scribbler 28g for workers.

26g " strippers.

Special Features. (1) Scotch Feed fitted with two rollers to press sliver on feed sheet.

(2) Caps on all bearings.

(3) Sheet iron plates fitted on sides of machine to keep down fly.

(4) Angles on Scribbler running "up hill."

(5) Workers on last swift of carder driven from swift and running in direction opposite to the usual.

(6) Two Fly Strippers on last doffer.

Remarks. This machine is intended for a class of material different from the blend used in this experiment. The action of the fancies is too violent. It was not possible to get sufficient rubbing action.

This test was started with the surface drums running at 39 r.p.m., but this was reduced to 29 r.p.m. The spin was thus appreciably improved.

Spinning. Whiteley Mule 300 spindles.

Net draw 6' 3½".

Mule fitted with Angola Scroll.

778 turns per draw, i.e., 10.3 turns per inch.

Output. (1) Lot B.—(Swifts at 82 revs. per min.)

Weight of yarn ... 389 lbs.

" fettlings and droppings ... 58 "

" condenser waste and spinning waste ... 25 "

Output of carding determined by observing the time required to fill bobbins and weighing the wool thereon, 25.8 lbs. per hour.

(2) Lot C.—(Swifts speeded down to 65 r.p.m.)

Surface drums 29 r.p.m.

∴ Rubber speed reduced in ratio 65:82.

Weight of yarn ... 401 lbs.

" fettlings and droppings ... 58 "

" condenser and spinning waste ... 25 "

LOTS D & E.

Cliffe's Hopper Feed—60" wide throughout—79 r.p.m.

Scribbler. Open belt drive from high speed shafting.

		36" pulleys on Carder and Scribbler	
		12" " on Shafting	
3 Feed Rollers		2" diam.	14's n.p.
Lickerin		12½"	16's n.p.
Angle		6"	60/6
Breast		36"	70/7
3	" Workers	9"	75/7
2	" Strippers	4½"	60/6
	" Fancy	12½"	40/4
Doffer		24"	60/6
1st Swift		43"	100/9
3	Workers	9"	110/10
3	Strippers	4½"	80/8
	Fancy	12½"	60/6
	Fly Stripper	2½"	80/8
Doffer		30"	110/10
Angle		6"	80/8
2nd Swift		43"	115/10
3	Workers	9"	120/10
3	Strippers	4½"	80/8
	Fancy	11½"	65/6
	Fly Stripper	2½"	80/8
Doffer		30"	120/10
Angle		6"	80/8

26 r.p.m.
148 "
52 "
9 "
130 "
262 "
80 "
64 "
9½ "
170 "
294 "
178 "
9½ "
78 "
62 "
7¼ "
160 "
308 "
312 "
7 "
86 "

3rd Swift	52" diam.	125/11	62 r.p.m.
4 Workers	9" "	130/11	11½ "
4 Strippers	4½" "	80/8	202 "
Fancy	12" "	70/7	332 "
Fly Stripper	2½" "	80/8	184 "
Doffer	30" "	130/11	5 "
Fly Comb and Scotch Feed.			

Carder.

3 Feed Rollers	2½" diam.	16's n.p.	40 r.p.m.
Lickerin	9" "	16's n.p.	200 "
Angle	6" "	80/8	60 "
1st Swift	50" "	130/11	12½ "
4 Workers	9" "	135/11	212 "
4 Strippers	4" "	100/9	318 "
Fancy	12" "	70/7	470 "
Fly Stripper	2½" "	90/9	11½ "
Doffer	33" "	135/11	160 "
Angle	6" "	90/9	60 "
2nd Swift	50" "	135/11	10½ "
4 Workers	9" "	135/12	182 "
4 Strippers	4½" "	100/9	316 "
Fancy	12" "	70/7	256 "
Fly Stripper	2½" "	90/9	3½ "
Tape Doffer	32" "	120/10	28 "
Stripping Roller	3½" "	120/10	

Redshaw-Lister Endless Tape Condenser—4 height.

Single rubbers.

100 good threads—2 waste.

Rubber eccentric speed 230 r.p.m.

Workers running " up hill " on last swift.

Surface Drums 9" diam. 14 r.p.m.

Setting.	Breast and 1st Swift	28g
	2nd and 3rd Swifts	30g
	Carder	32g

Spinning. Asa Lees Mule, 300 spindles 2½" pitch.

Net draw 6' 7"—2¼ jack.

Lot D. Surface drums 14 r.p.m.

Cardings 10¼ skeins.

Twist 816 turns per 6' 7", i.e., 10.3 turns per inch.

Output.	Weight of wool	464 lbs.
	" yarn	392 "
	" condenser and spinning waste ...	12 "
	" fettlings and droppings	29 "
	24.8 lbs. of 10¼ skein cardings per hour.	

LOT E. Was started with the surface drums 29½ r.p.m. but the rubber speed (255 r.p.m.) was not great enough to give satisfactory cardings. A larger rim pulley was therefore obtained and the eccentric speed was got up to 312 r.p.m.

In order to get the yarn sufficiently strong it was necessary to increase the twist to 12.6 turns per inch.

For the second part of this batch the speed of the surface drums was reduced to 21 r.p.m. This spun more satisfactorily than the first half with the same twist.

Output of $10\frac{1}{4}$ skein cardings at $29\frac{1}{2}$ r.p.m. is 53 lbs. per hour.

Scribbler—66" wide—iron throughout.

Carder. 60" wide.

Dick roller on tape doffer 110/10.

Platt Bros. Series Tape Condenser—4 height.

96 good threads—4 waste.
 Surface drums 9" diam. $15\frac{1}{2}$ r.p.m.
 Eccentric Speed about 300 r.p.m.

Spinning. Asa Lees Mule. 504 spindles, 2" pitch.

$70\frac{1}{4}$ " net draw.

829 turns per draw, i.e., 11.8 turns per inch.

Platt Spinning Frame.

Cardings 12 skeins.

Taking roller $1\frac{1}{2}$ " diam., 64 r.p.m.

Spindle Speed 1150 r.p.m.

In this test the cardings were condensed to $11\frac{1}{2}$ —12 skeins, and the spinning was not very satisfactory.

Output. Weight of wool ... 490 lbs.
 " yarn ... 365 lbs. (Mule 332—Frame 35)
 " condenser and spinning waste ... 45 lbs.
 " fettling waste ... 60 "
 24.6 lbs. of 12 skeins cardings per hour.

LOT G.

Platt Machine—Iron—60" wide.

Fillet clothing throughout.

Cliffe's Hopper Feed. Crossed Belt Drives.

Scribbler.

3 Feed Rollers	$2\frac{1}{2}$ " diam.	Garnett	34 r.p.m.
Lickerin	12" "	Garnett	160 "
Angle	4" "		46 "
Breast	36" "	115/10	8 $\frac{1}{2}$ "
2 Workers	7 & 8" "	120/10	78 "
2 Strippers	4" "		6 "
Doffer	30" "	120/10	316 "
Angle	6" "		106 "
Swift	50" "	120/11	8 $\frac{1}{2}$ "
4 Workers	8" "	125/11	280 "
4 Strippers	4" "		508 "
Fancy (covered)	$13\frac{1}{2}$ " "		8 $\frac{1}{2}$ "
Doffer	30" "	125/11	

Fly Comb and Balling Machine.

Patent traversing spiked cleaner on swift ($5\frac{1}{4}$ " wood cylinder, 700 r.p.m.)

" " " " doffer ($3\frac{1}{2}$ " wood cylinder, 11 r.p.m.)

Creel of 60 Balls

Intermediate.

3 Feed Rollers	$2\frac{1}{2}$ "	Garnett	70 r.p.m.
Lickerin	12" diam.	Garnett	342 "
Angle	7" "		99 "
Swift	50" "	125/11	8 $\frac{1}{2}$ "
5 Workers	8" "	130/11	362 "
5 Strippers	$3\frac{1}{4}$ " "		402 "
Fancy	$13\frac{1}{2}$ " "		8 $\frac{1}{2}$ "
Doffer	30" "	130/11	

Fly Comb and Balling Machine.

Creel of 60 balls.

Carder.

3 Feed Rollers	2½" diam.	Garnett	
Lickerin	12" "	Garnett	64 r.p.m.
Angle	7" "		336 "
Swift	50" "	130/11	110 "
5 Workers	8" "	135/12	8½ "
5 Strippers	3¼" "		356 "
Fancy (covered)	14" "		492 "
Doffer	30" "	135/12	8½ "
Dick Roller	3¼" "		23 "
Scotch Feed			
3 Feed Rollers	2" diam.		
Lickerin	3¼" "		142 r.p.m.
Tummer	9" "		194 "
Swift	50" "	135/12	80 "
6 Workers	8" "	140/12	5½ "
5 Strippers	3¼" "		262 "
Fancy	13½" "		364 "
Doffer	30" "	140/12	5½ "
Stripping Roller			41 "
Series Tap Condenser (Platt).			
3 Height—90 good threads.			
Tandem rubbers.			
Eccentric speed 306 r.p.m.			
Surface Drums 9".			
1st Creel of cardings at 32 r.p.m. of surface drums.			
Rest of cardings at 22 r.p.m. of surface drums.			
Cardings 11¼ skeins.			

Spinning. Platt Mule. 360 spindles.

72" net draw, 3" jack.

837 turns per draw, i.e., 11.6 turns per inch.

Output.	Weight of wool	...	...	...	...	490 lbs.
	" yarn	...	...	...	...	{ 191 " (at 32 r.p.m.)
	" soft waste	...	...	...	...	{ 159 " (at 22 r.p.m.)
	" fettlings	...	...	...	...	45 "
		...	...	...	...	90 "
	Output for machine, 35.4 lbs. per hour at 22 r.p.m.					

LOT H.Platt Machine 60" wide throughout. Crossed Belt Drives.
Cliffe's Hopper Feed.**Scribbler.**

3 Feed Rollers			
Lickerin	12" diam.		36 r.p.m.
Angle	4" "		180 "
Breast	36" "		52 "
2 Workers	8¼" "		6½ "
2 Strippers	4" "		120 "
Angle	6" "		383 "
Swift	50" "		120 "
5 Workers	7¼" "		6½ "
5 Strippers	3¼" "		474 "
Fancy	13½" "		547 "

Doffer	30" diam.	6 r.p.m.
Dick Roller	3 $\frac{1}{4}$ " "	18 "
Balling Machine.	Creel of 60 balls.	

Intermediate.

3 Feed Rollers		
Lickerin	9 $\frac{1}{2}$ " diam.	84 r.p.m.
Angle	7 $\frac{1}{4}$ " "	458 "
Swift	50" "	110 "
5 Workers	8 $\frac{1}{4}$ " "	6 "
5 Strippers	3 $\frac{1}{4}$ " "	424 "
Fancy (covered)	13 $\frac{1}{4}$ " "	494 "
Doffer	30" "	6 "
Dick Roller	3 $\frac{1}{4}$ " "	16 "
Balling Machine and Creel	of 60 balls.	

Carder.

3 Feed Rollers		
Lickerin	9 $\frac{1}{2}$ " diam.	82 r.p.m.
Angle	7 $\frac{1}{4}$ " "	410 "
Swift	50" "	110 "
5 Workers	8 $\frac{1}{4}$ " "	6 "
5 Strippers	3 $\frac{1}{4}$ " "	424 "
Fancy	13 $\frac{1}{4}$ " "	503 "
Doffer	30" "	5 $\frac{1}{2}$ "
Dick Roller	3 $\frac{1}{4}$ " "	16 "
Scotch Feed.		
3 Feed Rollers		
Lickerin	4" diam.	185 r.p.m.
Tummer	8 $\frac{3}{4}$ " "	212 "
Worker over Tummer	8 $\frac{3}{4}$ " "	9 $\frac{1}{2}$ "
Swift	50" "	98 "
5 Workers	7 $\frac{3}{4}$ " "	9 $\frac{1}{2}$ "
5 Strippers	3 $\frac{1}{4}$ " "	394 "
Fancy	13 $\frac{3}{4}$ " "	430 "
Tape Doffer	30" "	9 $\frac{1}{2}$ "
Stripping Roller	3 $\frac{1}{4}$ " "	76 "
Platt Tandem Rubber Tape Condenser.		
60 good threads.		
Surface drums 9", 41 r.p.m.		
Rubber eccentrics 414 r.p.m.		
Dividers between rubbers.		

Output.	Weight of wool ...	...	...	...	449 lbs.
	" yarn ...	...	...	...	308 $\frac{1}{2}$ "
	" soft waste ...	...	...	...	38 "
	" fettlings ...	...	...	...	20 "
	52 $\frac{1}{2}$ lbs. of 8 $\frac{1}{4}$ skeins cardings per hour.				

Spinning. Mules as for Lot G.

8 $\frac{1}{4}$ Skein cardings drawn to 12 skeins with 297 turns per 72" net draw left-hand twist. 15 secs. per draw. No jack. Rovings spun to nominal count with 1144 turns per 70" net draw right-hand twist, i.e., 924 turns per 70" draw net. 34 secs. per draw.

LOT J.

Machine 60" wide throughout. Open Belts.
Cliffe's Hopper Feed.

Scribbler. Iron.

3 Feed Rollers	1 $\frac{1}{4}$ " diam.		
Lickerin	12"		42 r.p.m.
Angle	4"		286 "
Breast	50"	100/9	72 "
5 Workers	8"	100/9	11 $\frac{1}{2}$ "
5 Strippers	3 $\frac{1}{4}$ "		230 "
Fancy	13 $\frac{1}{2}$ "	28g wire	270 "
Doffer	27"		8 $\frac{1}{2}$ "
Angle	6"		260 "
Swift	50"	120/10	110 "
4 Workers	8"		14 "
4 Strippers	3 $\frac{1}{4}$ "		290 "
Fancy	13 $\frac{1}{2}$ "	28g wire	492 "
Doffer	27"		8 "
Dick Roller	4"		21 "
Balling Machine and Creel of 60 balls.			

Intermediate and Carder.

3 Feed Rollers	1 $\frac{1}{4}$ " diam.	16's n.p.	
Lickerin	5 $\frac{1}{4}$ "		144 r.p.m.
Tummer	8"		266 "
Tummer Angle	3 $\frac{1}{4}$ "		8 "
Swift	50"	130/11	96 "
5 Workers	8"		8 "
5 Strippers	3 $\frac{1}{4}$ "		320 "
Fancy	13 $\frac{1}{2}$ "	28g wire	366 "
Doffer	27"		5 "
Scotch Feed.			
3 Feed Rollers	1 $\frac{1}{4}$ " diam.	Garnett	
Lickerin		Garnett	50 r.p.m.
Angle			300 "
Swift	50"	130/11	80 "
5 Workers	8"		4 $\frac{1}{2}$ "
5 Strippers	3 $\frac{1}{4}$ "		299 "
Fancy	13 $\frac{1}{2}$ "		264 "
Doffer	27"		6 "
Angle			146 "
Swift	50"	135/11	80 "
4 Workers	8"		4 $\frac{1}{2}$ "
4 Strippers	3 $\frac{1}{4}$ "		298 "
Fancy	13 $\frac{1}{2}$ "		256 "
Ring Doffer	36"		4 $\frac{1}{2}$ "
Tandem Rubbers.			
52 good threads.			
Surface drums 9" diam., 20 r.p.m.			
Rubber eccentrics, 414 r.p.m.			

Settings. 24g tight on breast and scribbler.
30g easy on carder.

Output.	Weight of wool ...	...	...	...	480 lbs.
	" yarn ...	...	...	...	364 "
	" soft waste ...	...	...	...	40 "
	" fettlings ...	...	...	...	40 "

18.4 lbs. per hour of 10 $1\frac{1}{5}$ skein cardings.

Spinning. Platt Mule 1872.

390 spindles $2\frac{1}{8}$ " pitch.

Net draw $69\frac{1}{2}$ ". 3" jack.

Twist 748 turns per $69\frac{1}{2}$ ".

Condition of Machine.—The carder swifts were in need of re-clothing. Otherwise the machine was in good condition.

LOT K.

Machine by Leach & Sons, Rochdale.

Cliffe Hopper

Machine 60" wide. Open Driving Belts.

Scribbler.

3 Feed Rollers			
Lickerin	$9\frac{1}{2}$ " diam.	28	r.p.m.
Angle	$4\frac{1}{2}$ " "	180	"
Breast	40" "	42	"
3 Workers	$8\frac{1}{4}$ " "	10	"
3 Strippers	$4\frac{1}{4}$ " "		
Fancy	$11\frac{1}{2}$ " "	300	"
Doffer	25" "	121	"
Angle	5" "	96	"
1st Swift	53" "	65	"
4 Workers	$8\frac{1}{4}$ " "	5	"
4 Strippers	$4\frac{1}{4}$ " "	268	"
Fancy	$11\frac{1}{2}$ " "	310	"
Doffer	30" "	8	"
Angle	5" "	156	"
2nd Swift	53" "	65	"
4 Workers	$8\frac{1}{4}$ " "	8	"
4 Strippers	$4\frac{1}{4}$ " "	268	"
Fancy	$13\frac{1}{2}$ " "	370	"
Fly Stripper	3" "	346	"
Doffer	30" "	6	"
Fly Comb and Scotch Feed.			
Covered Fancies.			

Carder.

2 Feed Rollers			
Lickerin	12" diam.	24	r.p.m.
Angle	5" "		
Breast	28" "	36	"
2 Workers	$7\frac{3}{4}$ " "	6	"
2 Strippers	4" "	80	"
Angle	6" "	80	"
1st Swift	50" "	70	"
4 Workers	$7\frac{3}{4}$ " "	8	"
3 Strippers	4" "	244	"
Fancy	$12\frac{1}{2}$ " "	340	"

Fly Stripper	3" diam.	
Doffer	27" "	8 r.p.m.
Angle	5" "	244 "
2nd Swift	50" "	70 "
4 Workers	7 $\frac{3}{4}$ " "	8 "
4 Strippers	4" "	244 "
Fancy	11 $\frac{1}{2}$ " "	344 "
Fly Stripper	3" "	
Tape Doffer	30" "	
Stripping Motion	3 $\frac{1}{2}$ " "	
Surface drums 9" diam. 13 $\frac{1}{2}$ r.p.m.		
4 Height Endless Tape Condenser, 120 good threads, 2 waste,		
8 small bobbins, tandem rubbers.		
Rubber eccentrics 284 r.p.m.		
Machine in excellent condition.		

Output.	Weight of wool...	...	...	...	510 lbs.
	" yarn...	...	...	...	400 "
	" soft waste	...	...	...	21 $\frac{1}{4}$ "
	" fettlings	...	...	...	86 "
29.6 lbs. per hour of 10 $\frac{1}{4}$ skein cardings.					

Spinning. Platt Mule.
70" Net Draw. 2" jack.
720 turns per draw.

LOT L.

Open Driving Belts.
Cliffe Hopper.

Scribbler. 72" wide. Wood.

3 Feed Rollers			
Lickerin	13 $\frac{1}{4}$ " diam.	16's n.p.	64 r.p.m.
Angle	4 $\frac{1}{2}$ " "		166 "
Breast	42" "		46 "
2 Workers	8 $\frac{1}{2}$ " "		9 $\frac{1}{2}$ "
2 Strippers	4 $\frac{1}{4}$ " "		186 "
Fancy	12" "		236 "
Doffer	33 $\frac{1}{2}$ " "		12 "
Angle	5 $\frac{1}{4}$ " "		114 "
1st Swift	50" "		82 "
3 Workers	8 $\frac{1}{2}$ " "		10 $\frac{1}{2}$ "
3 Strippers	4 $\frac{1}{2}$ " "		284 "
Fancy	13 $\frac{1}{2}$ " "		396 "
Fly Stripper	2 $\frac{1}{2}$ " "		422 "
Doffer	36" "		12 "
Angle	4 $\frac{1}{4}$ " "		110 "
2nd Swift	50" "		80 "
3 Workers	8 $\frac{1}{2}$ " "		6 "
3 Strippers	5 $\frac{1}{4}$ " "		254 "
Fancy	13 $\frac{1}{2}$ " "		308 "
Fly Stripper	2 $\frac{1}{2}$ " "		316 "
Doffer	36" "		8 $\frac{1}{2}$ "
Angle	5 $\frac{1}{4}$ " "		90 "
3rd Swift	52" "		82 "

4	Workers	8½" diam.	3 r.p.m.
4	Strippers	5¼" "	254 "
	Fancy	11½" "	404 "
	Fly Stripper	2½" "	390 "
	Doffer	36" "	3½ "
	Dickey	4½" "	8 "
	Fly Comb, Scotch Feed.		

Carder. 60" wide. Wood.

	3 Feed Rollers				
	Lickerin	8¼" diam.	16's n.p.	27	r.p.m.
	Angle	4¼" "		108	"
	Breast	36" "		38	"
2	Workers	8¼" "		8	"
2	Strippers	4¼" "		208	"
	Angle	5¼" "		280	"
	1st Swift	50" "		78	"
3	Workers	8¼" "		8	"
3	Strippers	5¼" "		222	"
	Fancy	14½" "		312	"
	Fly Stripper	2½" "		292	"
	Doffer	36" "	120/10	11	"
	Angle	5¼" "		94	"
	Last Swift	50" "	135/11	78	"
3	Workers	8¼" "	135/11	3	"
3	Strippers	5¼" "	120/10	196	"
	Fancy	13½" "	80/8	312	"
	Fly Stripper	2½" "		316	"
	Tape Doffer	36" "		3½	"
	Stripping Motion	3½" "		32	"
	Surface Drums	9" "		16	"

Platt. 3 Height Series Tape Condenser.
 2 Height single rubbers, not tandem.
 75 good threads, 2 waste.
 Rubber eccentrics 294 r.p.m.

Output.	Weight of wool ...	...	...	...	498 lbs.
	" yarn...	...	...	...	386 "
	" soft waste ...	...	...	...	9 "
	" fettlings ...	...	...	...	56 "
	20 lbs. per hour of 10¼ skein cardings.				

Spinning. Asa Lees Mule, 350 spindles.
 Net Draw 72". Jack 3¼".
 719 turns per draw.
 6 draws in 2 minutes.

APPENDIX III.

From Table C it is seen that the average counts of the 14 lots of yarn range from 13.8 to 16.5 skeins. Before a fair comparison can be made the strength of each yarn at some standard count must be determined.

The simplest assumption possible is that the strength of a yarn is proportioned to the thickness or weight, or inversely proportional to the count. The curve obtained by plotting strength and count would then be a rectangular hyperbola. Now any short length of such a curve may be treated as a straight line, thus assuming a linear relation between strength and count. Thus in Fig. 1 the individual strengths

obtained in the hank tests on Lot A are plotted against the counts. In order to find the straight line AB which fits these observations best, the method of least squares has been used, giving the position of the straight line free from personal error. The strength at any standard count can be read on this straight line, extended if necessary.

We find, however, that there is a fatal objection to this method. CD in Fig. 1 is the best straight line representing the observations on Lot D. (The tests are not plotted to avoid confusion). Here we see that the relative strengths of Lots A and D depend upon the count at which they are compared. At 16.63 skeins they are equal. At higher counts D is the stronger, and at lower counts A is the stronger. Hence it is clear that it is not permissible to assume a linear relation between strength and count.

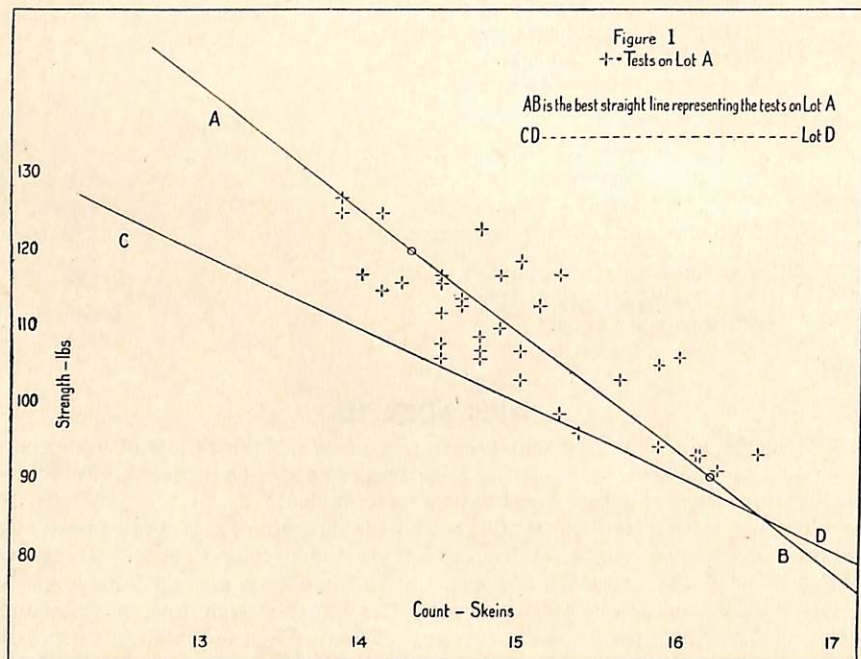
Now the assumption of proportionality between strength and weight involves no such objection. Expressed mathematically this method of reduction assumes the relation:—

$$\begin{aligned}\text{Strength} &= a \text{ constant} \times \text{weight} \\ \text{or } y &= m x \\ \text{To find } m \text{ we have } m &= \frac{\text{Sum of Strengths}}{\text{Sum of Weights}} \\ \text{or } m &= \frac{\sum y}{\sum x}\end{aligned}$$

The method of least squares would give for m the value

$\frac{\sum xy}{\sum x^2}$, but $\frac{\sum y}{\sum x}$ differs from $\frac{\sum xy}{\sum x^2}$ by about 1 part in 600 only, and the simpler expression is therefore quite accurate enough for all purposes. When m is known the strength corresponding to any given weight is readily calculated.

This method is equally simple graphically. The point representing the average strength and the average weight for a set of observations is plotted, and the point is joined to the origin. The strength at the standard weight can then be read off directly.



APPENDIX IV.

THE COEFFICIENT OF VARIATION.

The meaning of the coefficient of variation can best be illustrated by a fictitious example. Suppose in comparing the strengths of two yarns we get the following two series of tests :—

(1) 4.0, 4.5, 4.5, 5.0, 5.5, 5.5, 6.0 ozs.

and (2) 3.0, 4.0, 4.0, 5.0, 6.0, 6.0, 7.0 ozs.

(1) and (2) have each the same mean, viz., 5.0, yet (2) is obviously the more variable. Thus the arithmetic mean affords no criterion of variability.

In statistical work, the dispersion of the observations in a group is measured by a quantity known as the standard deviation. This is defined as the square root of the mean square of the deviations from the mean value. Thus if we have a series of n observations of strength y_1, y_2, y_3 , etc., of which the mean value is y_m , the standard deviation is

$$\sqrt{\frac{1}{n} \left[(y_m - y_1)^2 + (y_m - y_2)^2 + (y_m - y_3)^2 + \dots \right]}$$

The coefficient of variation is the standard deviation expressed as a percentage of the mean value.

$$\text{Coefficient of variation} = \frac{100 \times \text{Standard Deviation}}{\text{Mean}} \%$$

Reverting to the fictitious example above, we find for the standard deviations

$$(1) \sqrt{\frac{1}{7} \left[1^2 + \left(\frac{1}{2}\right)^2 + \left(\frac{1}{2}\right)^2 + \left(\frac{1}{2}\right)^2 + \left(\frac{1}{2}\right)^2 + 1^2 \right]} = \sqrt{\frac{3}{7}} = 0.65$$

$$\text{and (2)} \sqrt{\frac{1}{7} \left[2^2 + 1^2 + 1^2 + 1^2 + 1^2 + 2^2 \right]} = \sqrt{\frac{12}{7}} = 1.31$$

$$\text{and for the coefficients of variation we have (1) } \frac{0.65 \times 100}{5} = 13.0\%$$

$$\text{and (2) } \frac{1.31 \times 100}{5} = 26.2\%$$

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